FISH LADDERS IN THE PUNJAB.

BY

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(*With a map and two plates*).

Most of the common game and food fishes of the Province belong to the *Cyprinidae* (Carps), *Siluridae* (Cat-fishes), or *Ophiocephalidae* (Murrel). The Murrel are not migratory and breed in tanks, ponds and stagnant waters in April and May (Hamid Khan, 1924). A large number of the Carp and the Cat Fishes on the other hand show a tendency to migrate to a greater or lesser extent.

The Mahsir, one of the Carps, is by far the most important migratory species of all the fresh water fishes of India. It is a well known game and food fish. In summer as soon as the streams are swollen by the monsoon rains the Mahsir 'are able to ascend to parts of the river till then unapproachable for want of water. There they find fresh feeding grounds that are inaccessible to them at other times. There they deposit their spawn and thus secure for their fry when hatched, waters, then dwindled to dimensions much better suited to their puny strength than the deeper current of the lower river' (Thomas, 1897).

Most of the other Cyprinidae, too, such as Rohu (*Labeo rohita*), Morakha (*Cirrhina mrigala*), Theila (*Catla catla*) as well as some Siluridae, namely Bachwa (*Pseudeutropius garua*), Khagga (*Rita rita*) and others ascend the rivers during the monsoon rains in search of suitable spawning grounds and after laying their eggs in shallow waters return to the main stream (Hamid Khan, 1924).

It is, therefore, evident that for the propagation of the species of almost all the game and food fishes of the Punjab proper facilities are needed to enable them to ascend the rivers so as to reach such waters as will suit them to lay their spawn.

With the development of irrigation projects in the Punjab, dams or weirs have been constructed in the form of masonry works at the Headworks of the canals for the purpose of deflecting water into the canals. The weirs (Fig. 2) run across the entire width of the river and thus obstruct both the upward and the downward passage of fish. In order to enable the fish to ascend the head waters of the rivers and thus reach their spawning grounds for propagation, or to follow their migratory habits in search of food, fish passes or fish ladders (Fig. 3) have been provided in the weirs.

Weirs have been erected across the following rivers in the Punjab (Fig. 1).

1. River Jumna (near *Tajewala*).
2. River Sutlej (at *Ropar, Ferozepore, Suleimanki, Islam* and *Panjnad*).
3. River Ravi (at *Balloki, Madhopur* and *Sidhnai*).
4. River Chenab (at *Marala, Khanki* and *Trimmu*).
5. River Jhelum (at *Mangla* and *Rasul*).

Fish ladders have at present been provided by the Irrigation Department on all the weirs except at *Tajewala, Mangla* and *Sidhnai.* Most of the ladders have been in existence for over fifty years or so, but so far hardly any serious attention has been paid to ascertain their proper functioning. A survey of most of the fish ladders was made by the author and the outdoor Fisheries Staff in 1937-38, and as a result of it an attempt has been made in this paper to discuss the working of the ladders and to draw attention to such among them as are either not successful or only very moderately so.

Weir and its Structure.

Day, as early as 1873, described in detail the structure of a weir as having 'openings of varying sizes, termed undersluices, constructed for the purpose of permitting the surplus water passing through the body of the weir and on a level with the lowest bed of the river. These undersluices are kept shut except when there is an excess of water in the rivers, as during the monsoon months.' They close by means of iron shutters which can be elevated, when it is desired to do so, by capstan and windlass (Figs. 3 and 4). These narrow undersluices carry such a rush of water through them that no Indian fish can ascend the river when they are open (Fig. 2). Day (1873) recommended as one of the remedies to prevent injury to fisheries 'that every irrigation weir spanning a river have a practicable fish pass in it.' Dunsford (1911) drew the attention of the Punjab Government to the erection of fish passes and suggested certain principles which should be accepted for guidance. In 1916 the Department of Fisheries, Punjab, issued a Bulletin on 'Notes on Fish Ladders,' and recommended the 'Improved Cail Fish Pass' for the Punjab.[1]

Different Systems of Fish Passes. 'The underlying principle in the construction of fishways is the retardation of the current velocity of a waterfall so as to enable fish to surmount it.' (Bayer, 1908). In America and on the Continent innumerable devices with that object in view have been invented and proved more or less successful.

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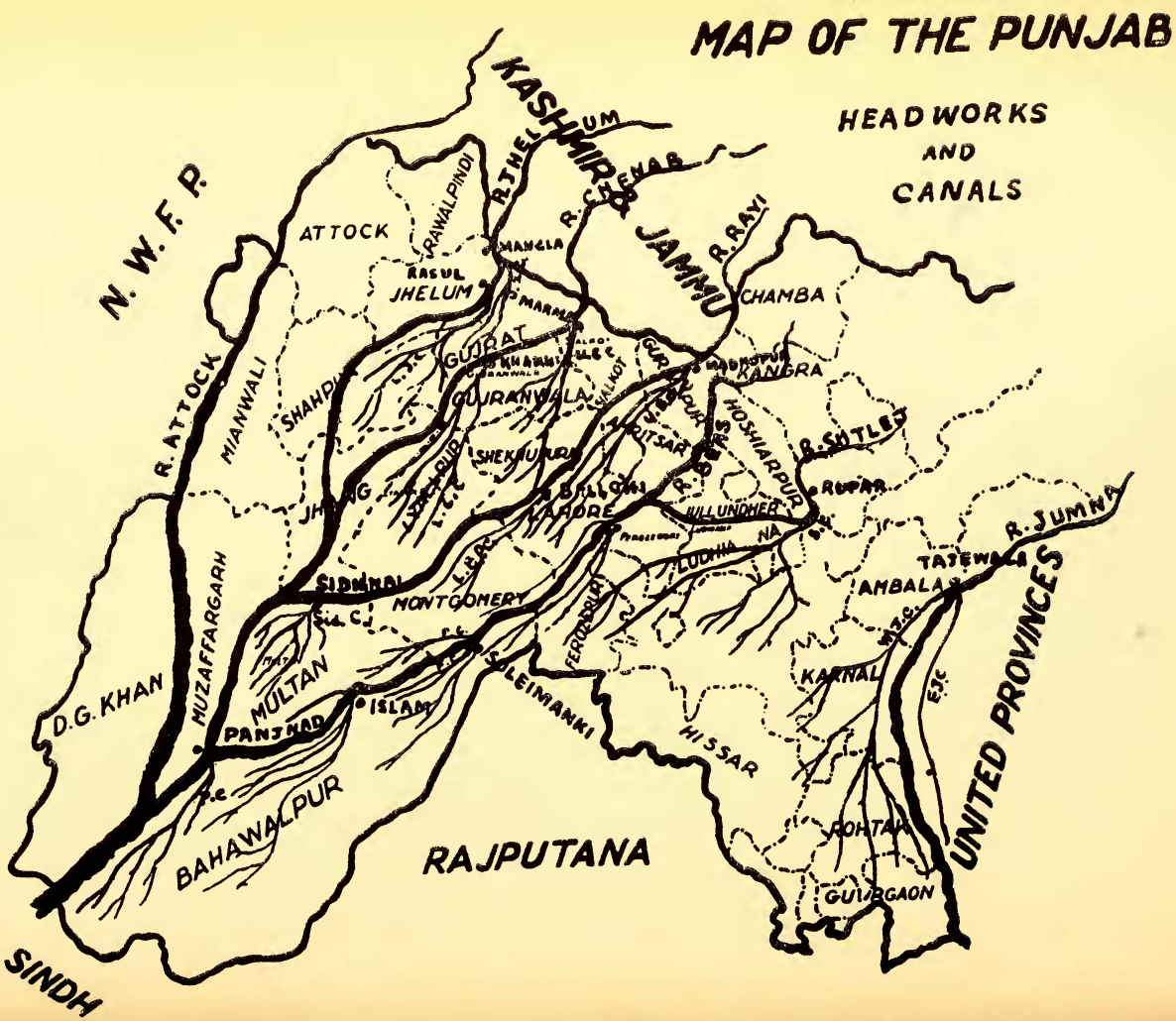
[1] The Cail Fish Pass was originally invented by Cail, an Engineer in New Castle, and improved upon by B. M. Hoecht, a German designer (Calderwood 1926). It was not invented by a German designer as is stated in the Bulletin No. 1 of the Department of Fisheries, Punjab, 1916. The Bulletin is out of print now.



Hamid Khan.—FISH LADDERS OF THE PUNJAB.

Bayer (1908) and Calderwood (1926) classify the fishways into four systems according to their style of construction:

1. *The Inclined Plane System,* in which the checks are so arranged that the descending water takes a zigzag course, being driven from side to side by an alternating arrangement of the breaks or baffle walls. Fish are, therefore, forced to take a sinuous course as they ascend.

2. *The Pool or Fall or Step System,* in which the water is brought down to a lower level by a series of short falls with intervening pools. This type of pass was invented by Cail, an Engineer in New Castle. Baffle walls were placed right across the width of the pass so as to form partitions. These were pierced by apertures large enough to allow a fish to pass, but not large enough to allow all the water in the pass to get through. Portion of the water flowed over the tops of the partitions too.[1]

3. *The Counter Current System,* in which the descending volume of water is checked by meeting a current opposing it at certain intervals. This pass was devised by McDonald (1882).

4. *Lock and Gate System,* in which a higher or lower level is reached through one or more locks operated by gates.

The systems 3 and 4 above are so complicated that they are practically very little in use now.

Main Requirements of a Fish Ladder.

Although every fish ladder, to a certain degree, has to be adapted to meet the special conditions of the locality, yet there are some general principles in all the four systems which may be accepted for guidance.

1. The slope of a fish ladder should not be steeper than one foot vertical to ten feet horizontal, so as to ensure a current of a velocity not exceeding ten feet per second in any portion of the fishway. The flow of the water should be gentle and without deep falls.

2. As regards the dimensions of the fish ladder, both the available volume of water and the size of the fish have to be considered. Since in the Punjab it is to be used by small fish such as Chilwa (*Aspidoparia morar*), not exceeding five or six inches in length, as well as by big fish such as Mahsir (*Barbus tor*), Rohu (*Labeo rohita*), Morakha (*Cirrhina mrigala*) and others which vary from one to three feet or even more in length, the falls should

[1] The Cail Fishway was improved by a German designer Hoecht. 'The improved Cail Fishway' is a combination of the inclined plane system with the pool and fall or step system. It consists of a series of compartments arranged in steps, and separated by a number of cross partitions, which are provided with suitable orifices at the bottom alternating successively from side to side so as to allow the fish according to their individual habits to ascend the fishway by either leaping over the small waterfalls over the cross partitions or by darting through the orifices, at the same time enabling them to rest in the compartments in comparatively still water.

average from eight to twelve inches and the width of each compartment should not be less than ten feet. 'The compartment or bays of the pass must be of such dimensions that the fish do not risk collision with the sides and upper end of each bay when ascending' (Dunsford, 1911).

3. 'Plenty of light should be admitted in a fishway, both for maintaining therein the natural conditions of the water, and in order that the interior may easily be inspected and any foreign matter removed' (Bayer, 1908). 'There must be nothing in the formation of the pass to suggest the existence of a trap' (Dunsford, 1911).

4. 'It should in all its parts, by action of the current of water passing through it, be as nearly as possible self cleaning of all sand, gravel and rubbish' (Bayer, 1908).

5. The water supply should be ample and there should always be water in the ladders in the season when the fish are making the ascent.

6. 'The top and side of a fishway should be above ordinary highwater' (Bayer, 1908).

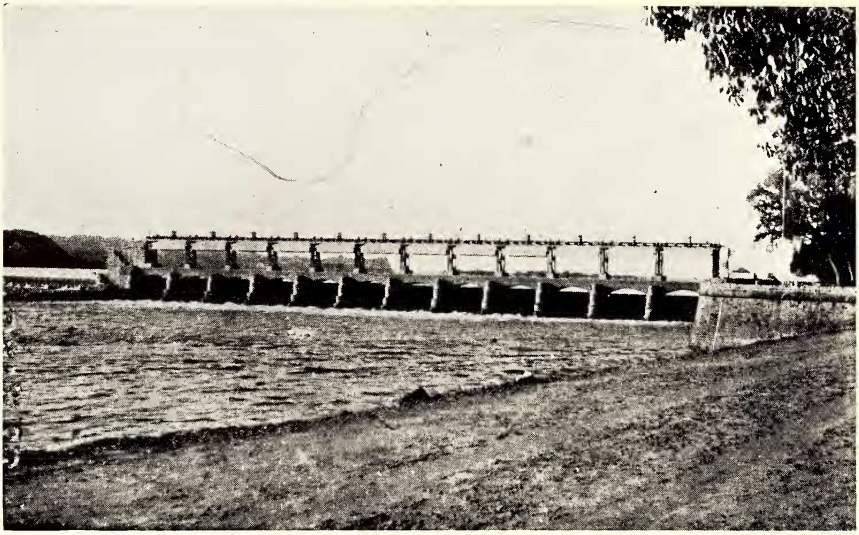
7. 'The pass must be situated where it will be self advertising; i.e. it must form a current impinging into a certain place below the obstacle so strongly that it becomes the chief or predominant current of the stream, when the fish will be led to that point for attempting the ascent' (Dunsford, 1911). 'One may have the best possible kind of pass, but if fish do not get into it one may as well have no pass at all. The position of the entrance is of paramount importance no matter what type of pass is selected. The ideal position for the entrance to the pass is close to where the fish lie, so that there will be an attractive flow of water from the pass, when the river is at the level at which they chiefly run' (Calderwood, 1926). The entrance should be located in a pool at the bottom of the ladder where fish would naturally collect before ascending the river, and these pools must be kept clear of all silt and other accumulations and deposits.

In the light of the knowledge gained from the descriptions of the various styles of fish passes existing in other countries, one may examine the fish passes constructed on the Headworks of the Canals in the Punjab.

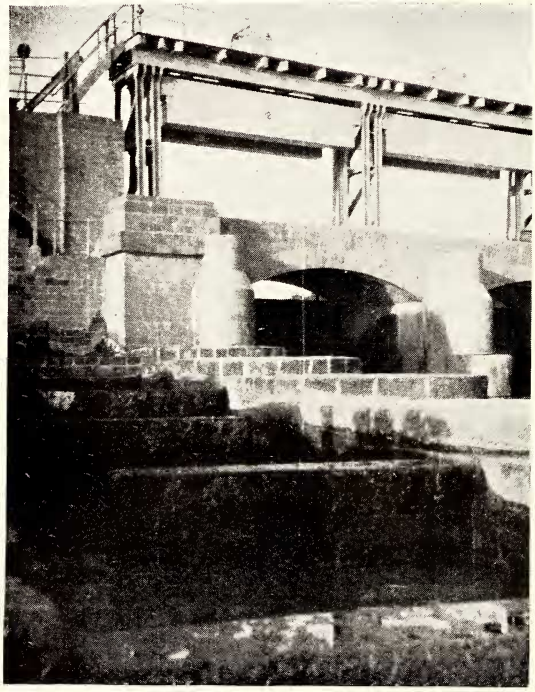
I am indebted to the Executive Engineers, Irrigation Department, Punjab, for providing me with facilities for the inspection of fish ladders and for furnishing me details of their design and construction.

River Jumna.

Tajewala Headworks. Tajewala, on the River Jumna, 25 miles from Jagadhari, is an old Headworks (constructed mainly between 1870 and 1880), where two canals, the Eastern Jumna Canal supplying the United Provinces, and the Western Jumna Canal going to Delhi and Hissar, take their origin shortly below the point of exit of this river from the hills. At Tajewala the river is furnished with gates for regulating the supply of water



Weir across River Sutlej at Rupar Headworks.



Fish ladder at Rupar.

to the canals. For full nine months of the year the gates are closed and not a drop of water passes down the river, and consequently the upward passage of all the fish in the river below the gates is totally obstructed. There is no fish ladder at the Headworks. It is only during the rains when surplus water is available that the weir and sluices are open to let the water into the main stream. At such time the velocity of the current through the undersluices prevents the fish from ascending upstream.

For more than fifty years the fish in the River Jumna, especially the Mahsir, have been deprived of the opportunity of ascending the hilly tracts in search of their spawning grounds. Mahsir begins to ascend the rivers in April and May and its passage is obstructed by the weir at Tajewala. Towards the end of September the fish in the upper reaches of the river above the weir begin to fall down the stream with the diminishing volume of water after the monsoon floods. At about the same time the sluices and the weir shutters at the Tajewala Head are completely closed and no water escapes into the river. The returning fish consequently pass into the canals. Once the fish have passed into the canals they have absolutely no chance to return to the river, as at Dadupur twelve miles down the Western Jumna Canal there is a rapid of 180 feet length, with a fall of about 15 feet, and it seems almost impossible for any fish to climb the rapid. Such fish are doomed to die and are caught during the canal closure.

A fish ladder at Tajewala is very badly needed, but at the same time it is very essential that it should not be a fish ladder only in name but should be made to work during the months when the fish are on the move. At Dadupur a system of steps and falls might be provided to break the velocity of the current without dismantling any of the existing engineering works.

River Sutlej.

Rupar. The weir (Plate I) across the River Sutlej at Rupar for deflection of water into the Sirhind Canal was constructed in 1882 and the fish ladder on the left side of it (Fig. 3) was also built in the same year. Its cost is not available in the records. It had originally fourteen bays. The first bay near the entrance measures 25 feet by 12 feet, the second 33 feet by 10 feet, and the remaining ones 10 feet by 10 feet. An additional bay was added to it at its upstream end and the downstream cross walls were raised by 1·5 feet, and the side walls by 2 feet during 1914-15, at an approximate cost of Rs. 950. The difference between the bed of the river upstream and downstream end of the left side ladder fish ladder (Plate I) in the right flank of the weir was built in 1921 at a cost of Rs. 3,432. It had 10 bays to begin with. During 1926-27 another compartment 7.5 feet by 9 feet was added, and beyond this a counter sunk trough was made for low winter supplies. To reduce the fall and help the Chilwas (*Aspidoparia morar*) to climb the ladder easily, the last two compartments were

split up into four at a cost of Rs. 788. The remaining compartments were also provided with cross walls in 1927-28 at a cost of Rs. 708. In the right side ladder there is a difference of about 9·51 feet between the levels at the downstream and upstream. The flow of water in both the ladders is regulated by means of wooden kurries fixed in the baffle walls. The width of the inlet, and outlet and the openings of the baffle walls is two feet. On the 11th April 1937 the right hand side fish ladder was found to contain two Mullies (*Wallago attu*), two Bachwas (*Pseudeutropius garua*) and one young Mahsir. The fish ladder on the left side, on the same day, was found to have one dozen Mahsir, and a dozen Bachwas, which were found to be ripe. One female Bachwa yielded eggs on slight pressure. The walls of the fish ladder, however, are too low and become flooded when the ladder is running full.

Ferozepore. The Bikaner Canal, the Eastern Canal and Depalpur Canal take their waters from the River Sutlej at Ferozepore weir which was completed in 1929. The fish ladder was originally constructed in 1927 at a cost of Rs. 98,623 and extended in 1929 at a cost of Rs. 15,591.

The fish ladder consists of 18 bays with incomplete baffle walls. The dimensions of the bays are 3 feet by 4 feet with a fall of about 6 inches in each. There is only one fish ladder and the flow of water in the bays is controlled by cement kurries. On the 17th April 1937 the ladder was seen full of Chilwas (*Aspidoparia morar*), young Bhangan (*Labeo micropthalmus*). Big fish such as Mahsir, Rohu, Morakha and others were not met with, but it is said that they move up the ladder, when the head of water on the upstream of the ladder increases and the ladder is running full.

Suleimanki. The Sadiqia, the Fordwah and the Pakpattan Canals take their waters from the River Sutlej at Suleimanki. The weir, and both the right and left side fish ladders were constructed in 1926. The cost of each fish ladder was Rs. 59,000 approximately. The right fish ladder has 24 bays with incomplete walls, out of these 18 bays measure 12 feet by 9 feet each. The first compartment is 19·6 feet by 9 feet; and from the 19th to the 24th measure 7·5 feet by 5 feet. Previously the fish ladder had one long slope as in the *inclined plane system*, and the force of the current when water was run was too strong for fish to ascend. Subsequently, in 1931-32, the floor of each bay was raised at a total cost of Rs. 6,715 to make a fall of 6 inches. The total length of the ladder is 308 feet. The upstream bed of ladder is R.L. 560·9 and the downstream bed R.L. 543·6, the difference being 17·3 feet. The slope is 1 in 15 per compartment in the first 18 compartments, and 1 in 5·6 per compartment in the last six. The dimensions of the openings in the baffle walls are 2 feet, and of the inlet and outlet 3 feet. The water level in the ladder is controlled by kurries. On the 16th April 1937, the right fish ladder was seen to contain Chilwa (*Aspidoparia morar*), Jhalli (*Eutropiichthys vacha*), Rohu (*Labeo rohita*), Kalahan (*Labeo calbasu*) and Morakha (*Cirrhina mrigala*). Chilwa was in enormous numbers

in all the bays. The big fish were seen in the bays at the downstream side. The ladder has been recently remodelled to make falls at its outlets by raising the floor.

The fish ladder on the left side, built on 'inclined plane system' has still got one long slope from the upstream to the downstream with intervening incomplete baffle walls. The force of the current when water is run into it is too strong for fish to ascend at the time when there is no water in the river at the downstream, viz. close to the entrance of the ladder. During July, August and September when the river downstream has water, the head of the water at the upstream end of the fish ladder is not so high, and the difference between the level of the water in the river upstream and downstream is much reduced, the fish are then able to ascend the left fish ladder as well. There are grooves in the baffle walls of three bays; the kurries were put in these on the 16th April 1937 and a fall of 4 feet was thus created. Rohu (*Labeo rohita*), Kalahan (*Labeo calbasu*) Morakha (*Cirrhina mrigala*) and Theila (*Catla catla*) varying in weight from three to five seers were seen leaping near the fall. The fall being too high to be surmounted, the fish fell back in the lower bay.

The fact that one fish ladder is working satisfactorily should not be considered sufficient for such a long weir as that at Suleimanki. It would be giving a fair chance to fish near the left bank if the left fish ladder were remodelled and made to work satisfactorily throughout the season.

On the day of my visit to Headworks at Suleimanki a number of large sized carp such as Rohu (*Labeo rohita*) and Morakha (*Cirrhina mrigala*) and others were observed leaping against the iron shutters of the undersluices of the weir at places where water was leaking through the interspaces between the shutters and the wall of the weir. On attempting again and again, though invariably in vain, to ascend the narrow vents of the undersluices, the fish became bruised and fell down exhausted on the floor of the apron of the weir and were caught by the canal menials. On such occasions it is almost a common practice to simply hang down baskets and catch the leaping fish.

Islam Headworks. The Bahawalpur, the Mailsi and the Qaimpur Canals take their water from the river Sutlej at Islam. The weir was constructed in 1926, and reconstructed in 1930. The fish ladder was constructed in March 1930, at a cost of Rs. 3,86,752. Though constructed at such a high cost, the fish ladder has never served its purpose. It is more of a fish trap than a fish ladder. It has been constructed inside the Right Divide wall. Starting from the downstream the fish ladder consists of ten bays of trapezoidal shape, each measuring ten feet by eight feet. Further on the ladder consists of forty small compartments. Out of these, sixteen measure 4 ft. 8 ins. by 8 ft. each, and twenty-four measure 5 ft. 4 in. by 8 ft. each. The slope in the upstream compartments is one in twenty-four and in the downstream ones it is one in twenty-seven. The dimensions of the openings in the baffle walls are 1 ft. by 1½ ft. and of the inlet and outlet of the ladder 3 ft. 4 ins. by 4 ft. 4 ins. Kurries are provided in the inlet and outlet

for control of water. The ladder ends blindly in front of the upstream end. There are however two windows, each measuring $4\frac{1}{3}$ ft. by $3\frac{1}{3}$ ft. on each side of the ladder. The fish might enter the ladder from the downstream entrance, but it seems doubtful whether they can jump into the upstream pool through the windows when water is rushing through them with great velocity.

The total length of the ladder is 355 feet and the difference between its upstream and downstream levels is 16·75 feet. But as neither any steps nor a pool at the entrance of the ladder for the fish to collect before making the ascent are provided, the ladder as such has never worked properly.

Panjnad Headworks. The Panjnad and the Abbasia canals take their water from the River Sutlej at Panjnad. The weir as well as the ladder were constructed in 1931. The latter being incorporated in part of the length of divide groyne, it is not possible to give its cost separately.

The ladder consists of twenty bays, each measuring 7 feet by 8 feet with incomplete baffle walls, leaving an opening 2 feet wide. It is constructed on the Cail System with a fall of one foot at each bay. The difference between the upstream and the downstream level of the ladder is 20·5 feet. The working of the ladder has not been observed by the writer, but from the reports received it is said to be used both by the small as well as the large fish during the season.

River Ravi.

Madhopur Headworks. (Plate II). The Upper Bari Doab Canal takes its exit from the River Ravi at Madhopur. The weir was constructed in 1870, and for 58 years no passage for the fish existed in the weir. The total length of the weir is half a mile. It was in 1928 that a fish ladder was constructed at a cost of Rs. 4,018. The ladder (Plate II) consists of seventeen bays, measuring 8·5 feet by 5 feet with complete baffle walls, each having an opening two feet wide at its base for the passage of the fish. The fish ladder has, therefore, been constructed on the Cail system. The difference between the upstream and the downstream level of the ladder is 13 feet. The falls are created by means of wooden planks fixed in the grooves in the baffle walls. The slope is one in fifteen. The inlet of the seventeenth bay at the upstream end opens into a compartment measuring 34 ft. by 5 ft. which leads into another compartment measuring 25 ft. by 5 ft. The last compartment opens into the river just close to the inlet of the rafting bay. The flow of water from the river is controlled by gates.

The entrance of the ladder at the downstream end is not very conspicuous. The area in front of the fish entrance is liable to shingle upto a level higher than the minimum water surface level and such shingling closes the entrance and puts the ladder out of action when the river is low. The entrance is located in a divide wall and is not self advertising. Small fish run up the ladder, but the large ones seem to prefer the rafting bay which